

TITLE OF THE INVENTION

PHOTOSENSOR SYSTEM AND DRIVE CONTROL METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based upon and claims the  
5 benefit of priority from the prior Japanese Patent  
Applications No. 11-316650, filed November 8, 1999;  
No. 11-319605, filed November 10, 1999; and  
No. 2000-015981, filed January 25, 2000, the entire  
contents of which are incorporated herein by reference.

10 BACKGROUND OF THE INVENTION

The present invention relates to a photosensor  
system having a photosensor array constituted by  
two-dimensionally arraying a plurality of photosensors,  
and a drive control method thereof.

15 Imaging apparatuses such as electronic still  
cameras, video cameras, and the like have come to be  
very widely used. These imaging apparatuses employ  
a solid-state imaging device, such as a CCD (Charge  
Coupled Device), which serves as a photoelectric  
20 converting device for converting an image of a to-be-  
photographed subject into an image signal. As well  
known, the CCD has a structure in which photosensors  
(light receiving elements) such as photodiodes, or  
thin film transistors (TFT: Thin Film Transistor) are  
25 arranged in a matrix, and the amount of electron-hole  
pairs (the amount of charge) generated corresponding  
to the amount of light entering the light receiving

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section of each sensor is detected by a horizontal scanning circuit and vertical scanning circuit to detect the luminance of radiation.

In a photosensor system using such a CCD, it is necessary to respectively provide scanned photosensors with selective transistors for causing the scanned photosensor to assume a selected state. In place of the combination of the photosensor and the selective transistor, a photosensor (to be referred to as a double-gate photosensor hereinafter) is now being developed, which is formed of a thin film transistor having a so-called double-gate structure and has both a photosensing function and a selecting function.

FIG. 31A is a sectional view showing the structure of a double-gate photosensor 10. FIG. 31B is a circuit diagram showing the equivalent circuit of the double-gate photosensor 10.

The double-gate photosensor 10 comprises a semiconductor thin film 11 formed of amorphous silicon or the like,  $n^+$ -silicon layers 17 and 18, source and drain electrodes 12 and 13 respectively formed on the  $n^+$ -silicon layers 17 and 18, a top gate electrode 21 formed above the semiconductor thin film 11 via a block insulating film 14 and upper gate insulating film 15, a protective insulating film 20 provided on the top gate electrode 21, and a bottom gate electrode 22 provided below the semiconductor thin film 11 via

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a lower gate insulating film 16. The double-gate photosensor 10 is provided on a transparent insulating substrate 19 formed of glass or the like.

5 In other words, the double-gate photosensor 10 includes an upper MOS transistor comprised of the semiconductor thin film 11, source electrode 12, drain electrode 13, and top gate electrode 21, and a lower MOS transistor comprised of the semiconductor thin film 11, source electrode 12, drain electrode 13, and bottom gate electrode 22. As is shown in the equivalent circuit of FIG. 31B, the double-gate photosensor 10 is considered to include two MOS transistors having a common channel region formed of the semiconductor thin film 11, TG (Top Gate terminal), BG (Bottom Gate terminal), S (Source terminal), and D (drain Terminal).

10 The protective insulating film 20, top gate electrode 21, upper gate insulating film 15, block insulating film 14, and lower gate insulating film 16 are all formed of a material having a high transmittance of visible light for activating the semiconductor thin film 11. Light entering the sensor from the top gate electrode 21 side passes through the top gate electrode 21, upper gate insulating film 15, and block insulating film 14, and then enters the semiconductor thin film 11, thereby generating and accumulating charges (positive holes) in the channel region.

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FIG. 32 is a schematic view showing a photosensor system constituted by two-dimensionally arraying double-gate photosensors 10. As shown in FIG. 32, the photosensor system comprises a sensor array 100 that is constituted of a large number of double-gate photosensors 10 arranged in an  $n \times m$  matrix, top and bottom gate lines 101 and 102 that respectively connect the top gate terminals TG and bottom gate terminals BG of the double-gate photosensors 10 in a row direction, top and bottom gate drivers 111 and 112 respectively connected to the top and bottom gate lines 101 and 102, data lines 103 that respectively connect the drain terminals D of the double-gate photosensors 10 in a column direction, and an output circuit section 113 connected to the data lines 103.

In FIG. 32,  $\phi_{tg}$  and  $\phi_{bg}$  represent control signals for generating a reset pulse  $\phi_{Ti}$  and readout pulse  $\phi_{Bi}$ , respectively, which will be described later, and  $\phi_{pg}$  represents a pre-charge pulse for controlling the timing at which a pre-charge voltage  $V_{pg}$  is applied. In the above-described structure, as described later, the photosensing function is realized by applying a predetermined voltage from the top gate driver 111 to the top gate terminals TG, while the readout function is realized by applying a predetermined voltage from the bottom gate driver 112 to the bottom gate terminals BG, then sending the output voltage of the photosensors

10 to the output circuit section 113 via the data lines 103, and outputting serial data  $V_{out}$ .

FIGS. 33A to 33D are timing charts showing a method of controlling the photosensor system, and showing a detecting period ( $i$ -th row processing cycle) in the  $i$ -th row of the sensor array 100. First, a high-level pulse voltage (reset pulse; e.g.,  $V_{tg} = +15V$ )  $\phi_{Ti}$  shown in FIG. 33A is applied to the top gate line 101 of the  $i$ -th row, and during a reset period  $T_{reset}$ , reset operation for discharging the double-gate photosensors 10 of the  $i$ -th row is executed.

Subsequently, a bias voltage  $\phi_{Ti}$  of low level (e.g.,  $V_{tg} = -15V$ ) is applied to the top gate line 101 of the  $i$ -th row, thereby finishing the reset period  $T_{reset}$  and starting a charge accumulating period  $T_a$  in which the channel region is charged. During the charge accumulating period  $T_a$ , charges (positive holes) corresponding to the amount of light entering each sensor from the top gate electrode side are accumulated in the channel region.

Then, a pre-charge pulse  $\phi_{pg}$  shown in FIG. 33C with a pre-charge voltage  $V_{pg}$  is applied to the data lines 103 during the charge accumulating period  $T_a$ , and after a pre-charge period  $T_{prch}$  for making the drain electrodes 13 keep a charge, a bias voltage (readout pulse  $\phi_{Bi}$ ) of high level (e.g.,  $V_{bg} = +10V$ ) shown in FIG. 33B is applied to the bottom gate line 102 of the

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i-th row. At this time, the double-gate photosensors 10 of the i-th row are turned on to start a readout period  $T_{read}$ .

During the readout period  $T_{read}$ , the charges  
5 accumulated in the channel region serve to moderate  
a low-level voltage (e.g.,  $V_{tg} = -15V$ ) which has an  
opposite polarity of charges accumulated in the channel  
region and is applied to each top gate terminal TG.  
Therefore, an n-type channel is formed by the voltage  
10  $V_{bg}$  at each bottom gate terminal BG, the voltage  $V_D$  at  
the data lines 103 gradually reduces in accordance with  
the drain current with lapse of time after the pre-  
charge voltage  $V_{pg}$  is applied. More specifically, the  
tendency of change in the voltage  $V_D$  at the data lines  
15 103 depends upon the charges accumulating period  $T_a$  and  
the amount of received light. As shown in FIG. 33D,  
the voltage  $V_D$  tends to gradually reduce when the  
incident light is dark, i.e., a small amount of light  
is received, and hence only small charges are  
20 accumulated, whereas they tend to suddenly reduce when  
the incident light is bright, i.e., a large amount  
of light is received, and hence large charges are  
accumulated. From this, it is understood that the  
amount of radiation can be calculated by detecting the  
25 voltage  $V_D$  at the data lines 103 a predetermined period  
after the start of the readout period  $T_{read}$ , or by  
detecting a period required until the voltage  $V_D$

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reaches a predetermined threshold voltage.

Image reading is performed by sequentially executing the above-described drive-control for each line of the sensor array 100, by executing the control for each line in a parallel manner at different timings at which the driving pulses do not overlap.

Although the case of using the double-gate photosensor as a photosensor has been described above, even a photosensor system using a photodiode or phototransistor as a photosensor has operation steps: reset operation → charge accumulating operation → pre-charge operation → reading operation, and uses a similar drive sequence. The conventional photosensor system as above has the following problems.

(1) To read a subject image in various use environments in a photosensor system using the above-described photosensor, the reading sensitivity (charge accumulating period) must be properly set. The proper charge accumulating period changes depending on changes in ambient conditions such as the illuminance of external light in a use environment, and also changes when the characteristics of the photosensor change. In the prior art, therefore, a circuit for detecting the illuminance of external light must be additionally arranged. Alternatively, reading operation (to be referred to as pre-reading operation hereinafter) of changing the charge accumulating periods to a plurality

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of stages before the start of normal reading operation of a subject image must be executed to obtain the optimal value of the charge accumulating period from the read result. However, a reading sensitivity setting method of uniquely and automatically setting a proper charge accumulating period based on a read result every charge accumulating period that is obtained by pre-reading operation has not been developed yet.

(2) If a foreign substance attaches to the sensing surface of a photosensor or a defect is generated in a photosensor element in setting the reading sensitivity based on the result of pre-reading operation, and a read result obtained every charge accumulating period by pre-reading operation is directly used, an abnormal value is contained in the read result to fail in setting a proper charge accumulating period and inhibiting accurate reading operation of a subject image. For example, when this photosensor system is applied to a fingerprint reading apparatus, the apparatus may malfunction in fingerprint recognition processing.

#### BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to provide a reading sensitivity setting method of uniquely and automatically setting a proper reading sensitivity on the basis of read results obtained

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immediately before the start of normal reading  
operation of a subject image in order to accurately  
read a subject image in various use environments in  
a photosensor system having a photosensor array  
5 constituted by two-dimensionally arraying a plurality  
of photosensors. It is another object of the present  
invention to prevent any malfunction in setting the  
reading sensitivity even if a foreign substance  
attaches to the sensing surface of a photosensor, or  
10 a photosensor element becomes defective.

To achieve the above objects, a photosensor  
system according to the present invention comprises  
a photosensor array constituted by two-dimensionally  
arraying photosensors, a driver circuit for supplying  
15 a drive signal to the photosensors, a controller for  
controlling reading operation of a subject image and  
sensitivity setting, and a RAM for storing read image  
data, data relating to sensitivity setting processing,  
and the like.

To achieve the above objects, according to the  
20 first reading sensitivity setting method of the present  
invention, pre-reading operation of changing the charge  
accumulating period at a plurality of stages for, e.g.,  
respective rows is executed before the start of normal  
25 reading operation of a subject image. A row in  
which the dynamic range of lightness data for each  
row is maximum, or a row in which the displacement

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(differentiated value) of lightness data between rows in a specific column direction is maximum is extracted from read image data. An image reading sensitivity set for the extracted row is set as an optimal sensitivity.

5 This can reduce the data amount to be processed, simplify sensitivity setting processing, and shorten the required time. Even when the ambient light or the characteristics of the photosensor change, an optimal image reading sensitivity can be set in accordance with  
10 the changes.

To achieve the above objects, according to the second reading sensitivity setting method of the present invention, pre-reading operation of changing the charge accumulating period at a plurality of stages  
15 for, e.g., respective rows is executed before the start of normal reading operation of a subject image. A row in which the dynamic range is maximum and the linearly differentiated value of the dynamic range is minimum is extracted from the dynamic ranges of lightness data of  
20 read image data for respective rows, or the dynamic ranges of lightness data for respective rows from which high-frequency components upon changes in the dynamic ranges of the rows are removed. An image reading sensitivity set for the extracted row is set as  
25 an optimal sensitivity. A row corresponding to an appropriate image reading sensitivity can be extracted without any influence of an abnormal pixel generated

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by a foreign substance attached to the sensing surface of the photosensor array, a defect of the photosensor element, or the like. The present invention can provide a reliable reading sensitivity setting method.

5 Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and  
10 obtained by means of the instrumentalities and combinations particularly pointed out hereinafter.

#### BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate presently preferred embodiments of the invention,  
15 and together with the general description given above and the detailed description of the preferred embodiments given below, serve to explain the principles of the invention.

20 FIG. 1 is a block diagram showing an arrangement of a photosensor system according to the present invention;

FIG. 2 is a block diagram showing an arrangement of a controller applied to the first embodiment;

25 FIG. 3 is a flow chart showing the operation of the first embodiment;

FIG. 4 is a view showing an example of image data

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when a fingerprint image is read by pre-reading operation in the first embodiment;

FIGS. 5A to 5E are graphs each showing changes in lightness data in a specific row that are obtained by pre-reading operation in the first embodiment;

FIGS. 6A and 6B are views showing the relationship between a table representing the dynamic range of lightness data of each row that is obtained by pre-reading operation in the first embodiment, and a corresponding row number vs. image reading sensitivity correspondence table;

FIG. 7 is a view showing another example of image data when a fingerprint image is read by pre-reading operation in a modification of the first embodiment;

FIGS. 8A to 8E are graphs each showing changes in lightness data in the column range of a specific region in a specific row that are obtained by pre-reading operation in the modification of the first embodiment;

FIGS. 9A and 9B are tables showing the relationship between a table representing the dynamic range of lightness data of each row that is obtained by pre-reading operation in the modification of the first embodiment, and a corresponding row number vs. image reading sensitivity correspondence table;

FIG. 10 is a flow chart showing the operation of the second embodiment;

FIG. 11 is a view showing an example of image data

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when a fingerprint image is read by pre-reading operation in the second embodiment;

FIGS. 12A and 12B are graphs, respectively, showing the value of lightness data in a predetermined column that is obtained by pre-reading operation in the second embodiment, and the differentiated value of lightness data between rows;

FIGS. 13A and 13B are views showing the relationship between a table representing the differentiated value of lightness data between rows in a predetermined column that is obtained by pre-reading operation in the second embodiment, and a corresponding row number vs. image reading sensitivity correspondence table;

FIG. 14 is a flow chart showing the operation of the third embodiment;

FIG. 15 is a view showing examples of image data and a sensitivity determination range when a fingerprint image is read by pre-reading operation in the third embodiment;

FIG. 16 is a graph showing changes in lightness data of a specific row in the sensitivity determination range of image data read by pre-reading operation in the third embodiment;

FIGS. 17A and 17B are graphs showing the relationship between changes in the dynamic ranges of respective rows of image data read by pre-reading operation in the third embodiment, and changes in the

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linearly differentiated values of the dynamic ranges of respective rows;

FIGS. 18A and 18B are views showing the relationship between a table representing the dynamic range of each row and the linearly differentiated value of the dynamic range that are obtained by pre-reading operation in the third embodiment, and a corresponding row number vs. image reading sensitivity correspondence table;

FIGS. 19A and 19B are views showing the relationship between a table representing the dynamic range of each row and a corresponding row number vs. image reading sensitivity correspondence table when the first embodiment is applied to image data read by pre-reading operation in the third embodiment;

FIG. 20 is a view showing a case wherein an abnormal value exists in read image data of a fingerprint image in pre-reading operation in the third embodiment;

FIG. 21 is a graph showing changes in the dynamic ranges of respective rows when an abnormal value exists in read image data of a fingerprint image in pre-reading operation in the third embodiment;

FIGS. 22A and 22B are graphs showing the relationship between changes in the dynamic ranges of respective rows, and changes in the linearly differentiated values of the dynamic ranges of

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respective rows when an abnormal value exists in read image data of a fingerprint image in pre-reading operation in the third embodiment;

FIG. 23 is a flow chart showing the operation of the fourth embodiment;

FIG. 24 is a block diagram showing an arrangement of a controller applied to the fifth embodiment;

FIG. 25 is a flow chart showing the operation of the fifth embodiment;

FIG. 26 is a view showing a case wherein an abnormal value across a plurality of rows exists in read image data of a fingerprint image in pre-reading operation of the fifth embodiment;

FIG. 27A is a graph showing changes in the dynamic ranges of respective rows when an abnormal value across a plurality of rows exists in read image data of a fingerprint image in pre-reading operation of the fifth embodiment, and the dynamic range discretely varies for respective rows;

FIG. 27B is a graph showing the dynamic range distribution of lightness data of respective rows after abnormal value removing operation in the fifth embodiment;

FIGS. 28A to 28J are timing charts showing the first embodiment of an image reading sensitivity setting method applied to pre-reading operation in each embodiment;

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FIGS. 29A to 29J are timing charts showing the second embodiment of an image reading sensitivity setting method applied to pre-reading operation in each embodiment;

FIGS. 30A to 30H are timing charts showing an embodiment when an effective voltage adjusting period is set after pre-reading and image reading periods in a photosensor system drive control method according to the present invention;

FIG. 31A is a sectional view showing the structure of a conventional double-gate photosensor;

FIG. 31B is an equivalent circuit diagram showing the double-gate photosensor;

FIG. 32 is a schematic view showing a photosensor system constituted by two-dimensionally arraying double-gate photosensors; and

FIGS. 33A to 33D are timing charts showing a conventional drive method for the double-gate photosensor system.

#### DETAILED DESCRIPTION OF THE INVENTION

Methods of controlling a photosensor system according to the present invention will be described in detail with reference to the several views of the accompanying drawings. Although in embodiments described below, a double-gate photosensor is applied as a photosensor, the present invention is not limited to the double-gate photosensor, but is also applicable

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to a photosensor system using another type of photosensor.

FIG. 1 is a block diagram showing an arrangement of a photosensor system according to the present invention. The double-gate photosensor shown in FIG. 31A is used, and the arrangement of the photosensor system shown in FIG. 32 will be referred to if necessary. The same reference numerals as in the photosensor system shown in FIG. 32 denote the same parts.

As is shown in FIG. 1, the photosensor system according to an embodiment comprises a photosensor array 100 including double-gate photosensors 10 shown in FIG. 31A that are arrayed two-dimensionally, a top gate driver 111 for applying a predetermined reset pulse to a top gate terminal TG of each double-gate photosensor 10 at a predetermined timing, a bottom gate driver 112 for applying a predetermined readout pulse to a bottom gate terminal BG of each double-gate photosensor 10 at a predetermined timing, an output circuit section 113 constituted by an amplifier 116, and a column switch 114 and pre-charge switch 115 for reading a data line voltage and applying a pre-charge voltage to each double-gate photosensor 10, respectively, an analog/digital converter (to be referred to as an A/D converter hereinafter) 117 for converting the read data voltage as an analog signal into image data

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as a digital signal, a controller 120 which is adopted to control the operation of reading a subject image by the photosensor array 100, and to exchange data with an external function section 200, and which controls sensitivity setting in the present invention, and a RAM 130 that stores, for example, read image data, data relating to setting of a reading sensitivity described later.

The structure including the photosensor array 100, top gate driver 111, bottom gate driver 112, and output circuit section 113 is the same as and has the same function as the photosensor system shown in FIG. 32. In addition to this structure, this embodiment adopts the A/D converter 117, controller 120, and RAM 130 to enable various types of control as described below.

The controller 120 outputs control signals  $\phi_{tg}$  and  $\phi_{bg}$  to the top and bottom gate drivers 111 and 112, respectively, which, in turn, output predetermined voltages (reset pulse and readout pulse) to the top gate terminal TG and bottom gate terminal BG of each double-gate photosensor 10 of the photosensor array 100, respectively. The controller 120 also outputs a control signal  $\phi_{pg}$  to the pre-charge switch 115 to control execution of the operation of reading a subject image. A data line voltage read from the photosensor array 100 via the column switch 114 and amplifier 116 is converted into a digital signal by the A/D converter

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117, and supplied as image data. The controller 120 also has a function of executing predetermined image processing for image data, writing or reading image data into or from the RAM 130. The controller 120  
5 serves as an interface with the external function section 200 that executes predetermined processing such as image data identification, modification, and the like.

The controller 120 has another function of  
10 controlling control signals to be output to the top and bottom gate drivers 111 and 112 to set an optimal reading sensitivity for reading a subject image in accordance with ambient environments such as the illuminance of external light, i.e., an optimal  
15 charge accumulating period for each double-gate photosensor 10.

As will be described below, photosensor system drive control methods according to embodiments of the present invention are based on the arrangement of this  
20 photosensor system.

<First Embodiment>

The first embodiment of the photosensor system drive control method according to the present invention will be described with reference to the several views  
25 of the accompanying drawing.

FIG. 2 is a block diagram showing an arrangement of a controller 120 applied to the first embodiment.

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As shown in FIG. 2, the controller 120 comprises a device controller 121 for controlling a top gate driver 111, bottom gate driver 112, and output circuit section 113, a data controller 122 for managing various data  
5 such as image data, write data, and readout data to the RAM 130, and a main controller 123 which supervises the controllers 121 and 122 and interfaces with an external function section.

The controller 120 further comprises a data  
10 comparator 124 for comparing the sizes of specific measurement data based on image data input as a digital signal from a photosensor array 100 via an A/D converter 117 to extract maximum and minimum values, an adder 125 having a function of calculating, e.g.,  
15 the difference between measurement data, a data selector 126 for receiving processed image data via the A/D converter 117, data comparator 124, and adder 125, and switching write/readout in/from the RAM, re-input to the data comparator 124 and adder 125, and output to  
20 the external function section via the data controller 122 in accordance with the received data, and a sensitivity setting register 127 for changing control signals to be output from the device controller 121 to the top and bottom gate drivers 111 and 112 so as to  
25 optimize the reading sensitivity of the photosensor array on the basis of a control signal from the data controller 122.

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The operation of the first embodiment in the operation control method of the photosensor system using the above controller will be explained with reference to FIG. 3. FIG. 3 is a flow chart showing an operation up to read of a subject image with an optimal sensitivity according to the first embodiment in operation control of the photosensor system. This operation will be described by properly referring to the arrangement of the photosensor system shown in FIGS. 1 and 2.

In S11 (pre-reading step) of FIG. 3, the main controller 123 controls to set an image reading sensitivity for pre-reading operation in the sensitivity setting register 127 via the data controller 122, and pre-reads a subject image prior to normal reading operation of a subject image. Similar to normal image reading operation, pre-reading operation is done by executing a series of processes: reset operation → charge accumulating operation → pre-charge operation → readout operation. In pre-reading operation, the image reading sensitivity is changed stepwise for, e.g., respective rows of a subject image so as to read one subject image at a plurality of different sensitivities. The image reading sensitivities of respective rows are stored in the RAM 130 in, e.g., a table format (row number vs. image reading sensitivity correspondence table) in correspondence

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with row numbers. A detailed image reading sensitivity setting method will be described later.

In S12 (image data conversion step) of FIG. 3, the image data read by pre-reading operation is converted into a digital signal via the amplifier 116 and A/D converter 117, and input as lightness data corresponding to the bright/dark pattern of the subject image to the data comparator 124. In this case, the lightness data is expressed by, e.g., 256 gray levels.

In S13 (step of extracting the maximum and minimum values of each row) of FIG. 3, the data comparator 124 extracts the maximum and minimum values of each row from the lightness data input to the data comparator 124, and outputs them to the adder 125. That is, the data comparator 124 extracts lightness data representing a maximum value (gray level value of the brightest pixel) contained in each row, and lightness data representing a minimum value (gray level value of the darkest pixel).

In S14 (step of calculating the dynamic range of each row) of FIG. 3, the adder 125 calculates as a dynamic range the difference between the maximum and minimum values of lightness data of each row, and stores the dynamic range in the RAM 130 via the data selector 126. The adder 125 executes dynamic range calculation processing for all the rows.

In S15 (step of extracting a row number having

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a maximum dynamic range) of FIG. 3, the dynamic ranges of respective rows stored in the RAM 130 are read out via the data selector 126, and input to the data comparator 124, which extracts a row number having the maximum dynamic range among the dynamic ranges of the respective rows.

In S16 (sensitivity referring/extraction step) of FIG. 3, the row number vs. image reading sensitivity correspondence table stored in the RAM 130 is looked up based on the row number having the maximum dynamic range, and an image reading sensitivity, i.e., charge accumulating period set for this row is extracted.

In S17 (extracted sensitivity setting step) of FIG. 3, the data controller 122 rewrites the sensitivity setting register 127 to set the image reading sensitivity in the sensitivity setting register 127 to the extracted image reading sensitivity.

In S18 (subject image reading step) of FIG. 3, normal reading operation of a subject image is executed at the extracted image reading sensitivity set in the sensitivity setting register 127.

An example of applying the first embodiment of the photosensor system drive control method using the above-described controller to a fingerprint reading apparatus will be described with reference to FIGS. 4 to 6B.

FIG. 4 is a view showing an example of fingerprint

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image data when a subject (fingerprint) image is read while the image reading sensitivity is changed stepwise for respective rows in pre-reading operation. FIGS. 5A to 5E are graphs each showing changes in lightness data in a specific row that are obtained by pre-reading operation. FIGS. 6A and 6B are views for illustrating tables showing the relationship between the dynamic range of lightness data of each row that is obtained by pre-reading operation, and a row number vs. image reading sensitivity correspondence table. Assume that image data is read out in units of matrices of 256 rows  $\times$  196 columns. A larger lightness data value represents a brighter image, and a smaller lightness data value represents a darker image. In pre-reading operation, the image reading sensitivity is set higher (charge accumulating period is set longer) for a larger row number (upward in FIG. 4), and lower (charge accumulating period is set shorter) for a smaller row number (downward in FIG. 4). In FIG. 4, as the row number increases (upward in FIG. 4), the ridge/valley pattern of the fingerprint becomes weaker under the influence of external light, and at last is read as an almost invisibly bright image. On the other hand, as the row number decreases (downward in FIG. 4), the ridge/valley pattern of the fingerprint becomes darker, and at last is read as an almost invisibly dark image. The lightness data level is expressed by 256 gray

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levels, and its lower and upper limit values are set to 0 and 255, respectively.

In this image data, changes in lightness data in the 176th, 152nd, 128th, 104th, and 80th rows are extracted, and plotted as shown in FIGS. 5A to 5E.

In the 176th row, as shown in FIG. 5A, the sensitivity is set high, so that lightness data substantially converges to the upper limit value and hardly provides any information as image data. In the 152nd row, as shown in FIG. 5B, the sensitivity is set relatively high, lightness data reaches the upper limit value in some columns, and all the ridge/valley (bright/dark) patterns of image data cannot be read. To the

contrary, in the 128th row, as shown in FIG. 5C, lightness data does not reach either the upper or lower limit value on all the columns, and is distributed between the upper and lower limit values. In the 104th row, as shown in FIG. 5D, the sensitivity is set relatively low, and most of lightness data is

distributed between the upper and lower limit values. However, lightness data reaches the lower limit value on some columns, and all the ridge/valley patterns of image data cannot be read. In the 80th row, as shown in FIG. 5E, the sensitivity is set low, so that lightness data substantially converges to the lower limit value and hardly provides any information as image data.

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Maximum and minimum values are extracted as numerical data on the basis of changes in the lightness data distribution of each of the respective rows shown in FIGS. 5A to 5E, and the dynamic range is calculated as the difference and listed on a table as shown in FIG. 6A. In the 176th and 152nd rows, lightness data reaches the upper limit. Since the maximum value is fixed to 255, the dynamic range depends on the minimum value. In the 104th and 80th rows, lightness data reaches the lower limit. Since the minimum value is fixed to 0, the dynamic range depends on the maximum value. In contrast, in the 128th row, lightness data does not reach either the upper or lower limit, and thus the dynamic range depends on the difference between the maximum and minimum values of the lightness data. The 128th row can attain the largest dynamic range, compared to the 176th, 152nd, 104th, and 80th rows. In other words, it can be determined that lightness data in the 128th row is image data having a fine contrast corresponding to the ridge/valley pattern of a fingerprint, and an optimal image reading sensitivity is set.

The RAM 130 stores the row number vs. image reading sensitivity correspondence table shown in FIG. 6B, and stores image reading sensitivities, i.e., charge accumulating periods  $T_1$  to  $T_{256}$  for respective row numbers.

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The row number vs. image reading sensitivity correspondence table is looked up for the 128th row having the maximum dynamic range, thereby obtaining an image reading sensitivity, i.e., charge accumulating period  $T_{128}$  set for the 128th row.

If a subject (fingerprint) image is read using the obtained charge accumulating period  $T_{128}$ , the image can be satisfactorily read.

The first embodiment has exemplified only the 176th, 152nd, 128th, 104th, and 80th rows as rows subjected to extraction and calculation processes of the dynamic range of lightness data. As a matter of course, the same processes can be executed for all 256 rows. When extraction and calculation processes of the dynamic range of lightness data are performed not for all the rows but for only selected specific rows, like this embodiment, the number of data to be processed can be decreased to simplify processing and shorten the time required for sensitivity setting processing, and the operation can quickly shift to normal reading operation of a subject image.

A modification of the first embodiment will be described with reference to FIGS. 7, 8A to 8E, 9A, and 9B. FIG. 7 is a view showing another example of fingerprint image data when a subject (fingerprint) image is read while the image reading sensitivity is changed stepwise for respective rows in pre-reading

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operation. FIGS. 8A to 8E are graphs each showing changes in lightness data in the column range of a specific region in a specific row that are obtained by pre-reading operation. FIGS. 9A and 9B are tables showing the relationship between the dynamic range of lightness data of each row that is obtained by pre-reading operation, and a row number vs. image reading sensitivity correspondence table. In this modification, unlike the first embodiment, lightness data of each row used to extract maximum and minimum values is limited to the column range of a specific region, and maximum and minimum values in this column range are extracted.

More specifically, in reading the ridge/valley pattern of a fingerprint as a subject image, the peripheral portion of a finger (region representing the edge of a finger in FIG. 7) touches an image reading surface weaker than the center of the finger. In addition, the ridge/valley pattern of the peripheral portion is not clear, and is influenced by external factors such as external light incident via the semitransparent layer of a skin surface layer. This degrades the uniformity and relevance of image data. To prevent this, the modification processes lightness data limited to a column range around the center of a finger which is relatively hardly influenced by external factors and has a clear ridge/valley pattern,

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thereby achieving appropriate extraction processing of maximum and minimum values.

As shown in FIG. 7, the reading sensitivity of a subject image is set higher (charge accumulating period is set longer) for a larger row number. For example, changes in lightness data in a predetermined column range (85th column to 112th column) in the 176th, 152nd, 128th, 104th, and 80th rows are extracted and plotted as shown in FIGS. 8A to 8E. Similar to FIGS. 5A to 5E described above, only in the 128th row, lightness data does not reach either the upper or lower limit value in the entire column range partially limited, and is distributed between the upper and lower limit values. In the remaining rows, lightness data reaches the upper or lower limit value, and all the ridge/valley patterns of image data cannot be read.

FIG. 9A shows the results of extracting maximum and minimum values as numerical data on the basis of changes in lightness data distribution of each row, and calculating the dynamic range from the difference. It can be determined that the dynamic range of lightness data in the 128th row is maximum, and that image data having a fine contrast corresponding to the ridge/valley pattern of a fingerprint is obtained. That is, an optimal image reading sensitivity can be determined to be set.

As shown in FIG. 6B, the row number vs. image

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reading sensitivity correspondence table stored in the  
RAM 130 stores charge accumulating periods  $T_1$  to  $T_{256}$   
for respective row numbers. As shown in FIG. 9B, the  
row number vs. image reading sensitivity correspondence  
5 table is looked up for the 128th row having the maximum  
dynamic range, thereby attaining an image reading  
sensitivity set for the 128th row, i.e., charge  
accumulating period  $T_{128}$  of the double-gate  
photosensor.

10 The sensitivity setting method of this modifica-  
tion can determine a row in an optimal image reading  
state on the basis of the dynamic range of lightness  
data in a predetermined column range for each row in  
setting an optimal image reading sensitivity based on  
15 the results of pre-reading operation. Accordingly,  
the data amount to be processed can be decreased to  
simplify sensitivity setting processing and shorten  
the required time.

<Second Embodiment>

20 The second embodiment of a photosensor system  
drive control method to which the same controller as in  
the first embodiment can be applied will be described  
with reference to the several views of the accompanying  
drawing.

25 FIG. 10 is a flow chart showing an operation up to  
read of a subject image with an optimal sensitivity  
according to the second embodiment in operation control

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of the photosensor system. This operation will be described by properly referring to the arrangement of the photosensor system shown in FIGS. 1 and 2.

In S21 (pre-reading step) of FIG. 10, prior to normal reading operation of a subject image, a main controller 123 controls to set an image reading sensitivity for pre-reading operation in a sensitivity setting register 127 via a data controller 122, and executes pre-reading operation of reading a subject image at a plurality of different sensitivities while changing the image reading sensitivity stepwise for respective rows of the subject image. The image reading sensitivities of respective rows are stored as a row number vs. image reading sensitivity correspondence table in a RAM 130 in correspondence with row numbers. This pre-reading operation is the same as the operation in the first embodiment, and a detailed method of setting the image reading sensitivity (charge accumulating period) will be described below.

In S22 (image data conversion step) of FIG. 10, the image data read by pre-reading operation is converted into a digital signal via an amplifier 116 and A/D converter 117, and input as lightness data corresponding to the bright/dark pattern of the subject image to a data comparator 124. In this case, the lightness data is expressed by, e.g., 256 gray levels.

In S23 (data extraction step in the column

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direction) of FIG. 10, the data comparator 124 extracts lightness data on a selected column, and outputs it to an adder 125.

5 In S24 (differentiation processing step in the column direction) of FIG. 10, the adder 125 calculates the displacement (differentiated value) of each row in the column direction of the extracted luminance data, and stores the displacement in the RAM 130.

10 In S25 (step of extracting a row number having the maximum differentiated value) of FIG. 10, the differentiated values of lightness data stored in the RAM 130 are read out via the data selector 126, and input to the data comparator 124, which extracts a row number having the maximum differentiated value among  
15 the differentiated values of lightness data.

In S26 (sensitivity referring/extraction step) of FIG. 10, the row number vs. image reading sensitivity correspondence table stored in the RAM 130 is referred based on the row number having the maximum differentiated value, and an image reading sensitivity, i.e.,  
20 charge accumulating period set for this row is extracted.

In S27 (extracted sensitivity setting step) of FIG. 10, the data controller 122 rewrites the  
25 sensitivity setting register 127 to set the image reading sensitivity in the sensitivity setting register 127 to the extracted image reading sensitivity. In S28

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(subject image reading step) of FIG. 10, normal reading operation of a subject image is executed at the extracted image reading sensitivity set in the sensitivity setting register 127.

5           An example of applying the second embodiment of the photosensor system drive control method to a fingerprint reading apparatus will be described with reference to FIGS. 11 to 13B.

FIG. 11 is a view showing an example of  
10   fingerprint image data when a subject (fingerprint) image is read while the image reading sensitivity is changed stepwise for respective rows in pre-reading operation. FIGS. 12A and 12B are graphs, respectively, showing the value of lightness data in a predetermined  
15   column that is obtained by pre-reading operation, and the displacement (differentiated value) of lightness data between rows. FIGS. 13A and 13B are tables showing the relationship between the displacement of  
20   lightness data between rows in a predetermined column that is obtained by pre-reading operation, and a row number vs. image reading sensitivity correspondence table. Assume that image data is read out in units of matrices of 256 rows  $\times$  196 columns. A larger  
25   lightness data value represents a brighter image, and a smaller lightness data value represents a darker image.

In pre-reading operation, the image reading sensitivity is set higher (charge accumulating period

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is set longer) for a larger row number (upward in FIG. 11), and lower (charge accumulating period is set shorter) for a smaller row number (downward in FIG. 11). For example, lightness data of respective rows (1st to 256th rows) on the 98th column are extracted and plotted as shown in FIG. 12A.

In a region having a small row number, the image reading sensitivity is set low, and lightness data converges to the lower limit value. In a region having a large row number, the image reading sensitivity is set high, and lightness data converges to the upper limit value. To the contrary, in a region around the central row (128th row), lightness data does not reach either the upper or lower limit value, and is distributed between the upper and lower limit values. Further, lightness data tends to change from the lower limit value to the upper limit value.

Differentiated values representing the displacements of lightness data of respective rows are calculated based on changes in lightness data of these rows, and plotted to obtain a distribution as shown in FIG. 12B. The distribution of the differentiated value of lightness data shown in FIG. 12B is listed on a table as shown in FIG. 13A. From this table, the differentiated value is observed to maximize between the 125th and 126th rows, and image data having a fine contrast corresponding to the ridge/valley pattern of

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the fingerprint is determined to be obtained. That is, an optimal image reading sensitivity can be determined to be set.

Similar to the table shown in FIG. 6B, the row number vs. image reading sensitivity correspondence table stored in the RAM 130 stores charge accumulating periods  $T_1$  to  $T_{256}$  for respective row numbers. This table is looked up for the 125th and 126th rows having the maximum differentiated value to acquire image reading sensitivities set for the 125th and 126th rows, i.e., charge accumulating periods  $T_{125}$  and  $T_{126}$  of the photosensor. The sensitivity setting register is rewritten to set a set value determined based on the two charge accumulating periods  $T_{125}$  and  $T_{126}$ , i.e., the average of the charge accumulating periods  $T_{125}$  and  $T_{126}$ . A subject (fingerprint) image is read at this optimal image reading sensitivity.

Similar to the modification of the first embodiment, the column number of lightness data to be processed is desirably specified to a column around the central portion of a subject (finger) which is relatively hardly influenced by external factors and at which the bright/dark pattern (ridge/valley pattern) of a subject image can be read clearly.

In setting an optimal image reading sensitivity based on the results of pre-reading operation, the sensitivity setting method of the second embodiment can

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easily determine a row in an optimal image reading state on the basis of the displacement of lightness data of each row in a specific column, and can set an image reading sensitivity (charge accumulating period) set for this row as an optimal sensitivity. Lightness data to be processed suffices to be one column (i.e., several rows), and data to be processed in sensitivity setting processing can be greatly decreased to further simplify sensitivity setting processing and shorten the required time.

<Third Embodiment>

The third embodiment of a photosensor system drive control method according to the present invention will be described with reference to the several views of the accompanying drawings.

The arrangement of a controller applied to the third embodiment has the same arrangement block as that in the first and second embodiments shown in FIG. 2. In addition, an adder 125 calculates a dynamic range from the difference between the maximum and minimum values of measurement data, and calculates the difference between respective dynamic ranges, i.e., linearly differentiated value. A data comparator 124 has a function of extracting the maximum value of a dynamic range calculated by the adder 125, and the minimum or maximum value of the difference (linearly differentiated value) between dynamic ranges.

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FIG. 14 is a flow chart showing an operation up to read of a subject image with an optimal sensitivity according to the third embodiment in the photosensor system operation control method using the above controller. This operation will be described by properly referring to the arrangement of the photosensor system shown in FIGS. 1 and 2.

In S31 (pre-reading step) of FIG. 14, prior to normal reading operation of a subject image, a main controller 123 controls to set an image reading sensitivity for pre-reading operation in a sensitivity setting register 127 via a data controller 122, and executes pre-reading operation of reading a subject image at a plurality of different sensitivities while changing the image reading sensitivity stepwise for respective rows of the subject image. The image reading sensitivities of respective rows are stored as a row number vs. image reading sensitivity correspondence table in a RAM 130 in correspondence with row numbers. This pre-reading operation is the same as the operation in the first embodiment, and a detailed method of setting the image reading sensitivity (charge accumulating period) will be described below.

In S32 (image data conversion step) of FIG. 14, the image data read by pre-reading operation is converted into a digital signal via an amplifier 116

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and A/D converter 117, and input as lightness data corresponding to the bright/dark pattern of the subject image to a data comparator 124. In this case, the lightness data is expressed by, e.g., 256 gray levels.

5           In S33 (step of extracting the maximum and minimum values of each row) of FIG. 14, the data comparator 124 extracts the maximum and minimum values of lightness data of each row, and outputs them to an adder 125. That is, the data comparator 124 extracts lightness  
10           data representing a maximum value (gray level value of the brightest pixel) contained in each row, and lightness data representing a minimum value (gray level value of the darkest pixel).

          In S34 (step of calculating the dynamic range of  
15           each row) of FIG. 14, the adder 125 calculates as a dynamic range the difference between the maximum and minimum values of lightness data of each row, and stores the dynamic range in the RAM 130 via the data selector 126. The adder 125 executes dynamic range  
20           calculation processing for all the rows.

          In S35 (step of calculating the linearly  
differentiated value of the dynamic range) of FIG. 14, the dynamic ranges of respective rows stored in the RAM 130 are read out via the data selector 126, and input  
25           again to the adder 125, which calculates the difference (linearly differentiated value) between the dynamic ranges of adjacent rows. The results are stored in the

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RAM 130 via the data selector 126.

5 In S36 (step of extracting a row number having  
a maximum dynamic range and minimum linearly  
differentiated value) of FIG. 14, data of the dynamic  
ranges of respective rows and data of the linearly  
differentiated values of the dynamic ranges which are  
stored in the RAM 130 are read out via the data  
selector 126, and input to the data comparator 124,  
which extracts a row number at which the dynamic range  
10 maximizes and the linearly differentiated value of the  
dynamic range minimizes (to 0 or a value close to 0).

In S37 (sensitivity referring/extraction step) of  
FIG. 14, the row number vs. image reading sensitivity  
correspondence table stored in the RAM 130 is looked up  
15 based on the extracted row number, and an image reading  
sensitivity, i.e., charge accumulating period set for  
this row is extracted.

In S38 (extracted sensitivity setting step) of  
FIG. 14, the data controller 122 rewrites the  
20 sensitivity setting register 127 to set the image  
reading sensitivity in the sensitivity setting register  
127 to the extracted image reading sensitivity. In S39  
(subject image reading step) of FIG. 14, normal reading  
operation of a subject image is executed at the  
25 extracted image reading sensitivity set in the  
sensitivity setting register 127.

An example of applying the third embodiment of

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the photosensor system drive control method to a fingerprint reading apparatus will be described with reference to FIGS. 15 to 18B.

FIG. 15 is a view showing an example of image data when a subject (fingerprint) image is read while the image reading sensitivity is changed stepwise for respective rows in pre-reading operation. FIG. 16 is a graph showing changes in lightness data of respective pixels of a specific row in the column direction that are obtained by pre-reading operation. FIGS. 17A and 17B are graphs showing the relationship between changes in the dynamic ranges of respective rows and changes in the linearly differentiated values of the dynamic ranges of respective rows. FIGS. 18A and 18B are views for illustrating tables showing the relationship between the dynamic range of each row and the linearly differentiated value of the dynamic range that are obtained by pre-reading operation, and a row number vs. image reading sensitivity correspondence table.

Assume that image data is read out in units of matrices of 256 rows  $\times$  196 columns. A larger lightness data value represents a brighter image, and a smaller lightness data value represents a darker image.

In pre-reading operation, the image reading sensitivity is set higher (charge accumulating period is set longer) for a larger row number (upward in FIG. 15), and lower (charge accumulating period is

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set shorter) for a smaller row number (downward in  
FIG. 15). In FIG. 15, as the row number increases  
(upward in FIG. 15), the ridge/valley pattern of the  
fingerprint becomes weaker under the influence of  
5 external light, and at last is read as an almost  
invisibly bright image. On the other hand, as the row  
number decreases (downward in FIG. 15), the ridge/  
valley pattern of the fingerprint becomes darker, and  
at last is read as an almost invisibly dark image.  
10 The lightness data level is expressed by 256 gray  
levels, and its lower and upper limit values are set to  
0 and 255, respectively.

In this image data, a sensitivity determination  
range used to extract a row having an optimal  
15 sensitivity is preferably limited to a region having a  
fine contrast corresponding to the ridge/valley pattern  
of the fingerprint. This embodiment will exemplify  
sensitivity setting processing when a row/column range  
defined by 64th to 191st rows and 67th to 130th columns  
20 is set as the sensitivity determination range.

In the sensitivity determination range shown in  
FIG. 15, for example, changes in lightness data in  
the 64th, 96th, 160th, and 191st rows are extracted  
and plotted as shown in FIG. 16. In the 191st row  
25 (represented by the broken line in FIG. 16) and 160th  
row (represented by the thin line in FIG. 16) within  
the row range, the sensitivity is set high, and

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lightness data converges to a large value (about 220 to 225) and hardly provides any information as image data. In the 96th row (represented by the thick line in FIG. 16), lightness data does not converge to either the upper or lower limit value on all the columns, and exhibits a relatively large vertical displacement corresponding to the bright/dark pattern of image data. In the 64th row (represented by the chain line in FIG. 16), the sensitivity is set low, so that lightness data converges to a small value (about 35) and hardly provides any information as image data.

Maximum and minimum values are extracted from the lightness data distribution of each row, and the difference is calculated to obtain a dynamic range. Obtained dynamic ranges are plotted for row numbers to attain a distribution curve having a maximum value MA in a predetermined row, as shown in FIG. 17A. Further, linear differentiation for the dynamic range distribution, i.e., the slopes of the dynamic range distribution curve for respective rows are calculated, and plotted for row numbers. As shown in FIG. 17B, a linearly differentiated value MB is 0 in a row exhibiting the maximum value MA.

It can be determined that lightness data in the row exhibiting the maximum dynamic range and minimum linearly differentiated value is image data having a fine contrast corresponding to the ridge/valley

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pattern of a fingerprint, and an optimal image reading sensitivity is set.

Maximum and minimum values are extracted as numerical data on the basis of changes in the lightness data distribution of each row shown in FIG. 16, and a dynamic range calculated from the difference and a linearly differentiated value calculated from the difference of the dynamic range of each row are listed on a table as shown in FIG. 18A.

In FIG. 18A, when the dynamic range maximizes at  $R_k$  in FIG. 18A, and the linearly differentiated value minimizes at  $D_{k-1}$  in FIG. 18A, rows  $L_{k-1}$  and  $L_k$  are extracted as row numbers at which the dynamic range maximizes and the linearly differentiated value minimizes.

As shown in FIG. 6B, the RAM 130 stores a row number vs. image reading sensitivity correspondence table within the sensitivity determination range, and stores image reading sensitivities, i.e., charge accumulating periods  $T_{64}$  to  $T_{191}$  for respective row numbers.

This row number vs. image reading sensitivity correspondence table is looked up for the extracted rows to extract image reading sensitivities, i.e., charge accumulating periods  $T_{k-1}$  and  $T_k$  set for the rows  $L_{k-1}$  and  $L_k$ , which are determined as optimal values. The sensitivity setting register 127 is

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rewritten to set, as an optimal image reading sensitivity, a set value determined based on the two extracted charge accumulating periods  $T_{k-1}$  and  $T_k$ , i.e., the average of the charge accumulating periods  $T_{k-1}$  and  $T_k$ . A subject (fingerprint) image is read at this optimal image reading sensitivity.

Note that in the distributions of the dynamic range and linearly differentiated value shown in FIGS. 17A and 17B, the linearly differentiated value of a row whose dynamic range has the maximum value MA is 0. In practice, however, a row whose linearly differentiated value is 0 may not exist. Thus, as conditions for extracting a row set to an optimal sensitivity, a row exhibiting the maximum dynamic range and the minimum linearly differentiated value (value nearest to 0) is extracted.

As will be described below, the third embodiment can effectively prevent any malfunction in optimal sensitivity extraction processing even when lightness data contains an abnormal value due to a small foreign substance attached to the fingerprint reading surface of the photosensor, a defect of the photosensor, or the like. This will be explained with reference to FIGS. 19A to 22B.

FIGS. 19A and 19B are tables showing the relationship between the dynamic range distribution of respective rows and a row number vs. image reading

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sensitivity correspondence table when the first embodiment is applied as another setting method of setting the optimal sensitivity of the photosensor system. According to this setting method, the optimal value of the image reading sensitivity is determined using a row whose dynamic range has the maximum value MA in the dynamic range distribution (see FIG. 17A) of lightness data in sensitivity setting processing described above.

In this sensitivity setting method, as described above, the dynamic range is calculated based on the lightness data distribution (maximum and minimum values) of each row in FIG. 19A, a row ( $L_k$  in FIG. 19A) having the maximum value (e.g.,  $R_k$  in FIG. 19A) is extracted, and an image reading sensitivity (charge accumulating period  $T_k$ ) set for the row  $L_k$  is extracted and determined as an optimal value.

Operation processing when lightness data contains an abnormal value, and comparison with the third embodiment will be explained.

FIG. 20 is a view showing still another example of image data when a subject (fingerprint) image is read while the image reading sensitivity is changed stepwise for respective rows in pre-reading operation. FIG. 21 is a graph showing changes in the dynamic ranges of respective rows. FIGS. 22A and 22B are graphs showing the relationship between changes in the dynamic ranges

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of respective rows, and changes in the linearly differentiated values of the dynamic ranges of respective rows.

As shown in FIG. 20, the sensitivity determination range is set to a row/column range defined by 64th to 191st rows and 67th to 130th columns, similar to FIG. 15, as a region having a fine contrast corresponding to the ridge/valley pattern of a fingerprint in order to extract a row having an optimal sensitivity from image data of the fingerprint. In this case, if an abnormal pixel IL1 exists in a row L within the sensitivity determination range owing to a foreign substance attached to a fingerprint reading surface, a defect of the photosensor, or the like, lightness data of the abnormal pixel IL1 may exhibit an excessive value in comparison with peripheral pixel data. This occurs when, for example, a black point exists on the white background, or a white point exists on the black background. In the distribution of a dynamic range calculated based on the maximum and minimum values of lightness data, the dynamic range of the row L containing the abnormal pixel IL1 appears greatly apart from the change trend of the entire distribution. If the setting method of the first embodiment in which an image reading sensitivity corresponding to a row having the maximum dynamic range is adopted as an optimal value is applied to pre-read image data,

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the dynamic range of the row L containing the abnormal pixel IL1 that is irrelevant to an original maximum value MA1 in the change trend of the dynamic range distribution is extracted as a maximum value MA2, and  
5 an image reading sensitivity set for the row L having this dynamic range is determined to be an optimal value. In this case, an improper image reading sensitivity (e.g., charge accumulating period longer than an optimal value) is set in the photosensor  
10 system. In normal reading operation, accurate reading operation may fail such that a subject image becomes white.

To the contrary, the sensitivity setting method of the third embodiment sets an optimal image reading  
15 sensitivity using conditions of extracting a row number at which the dynamic range exhibits the maximum value MA1 and the linearly differentiated value of the dynamic range exhibits a minimum value MB1 within a range where the dynamic range coincides with the  
20 entire dynamic range change trend. For this reason, the third embodiment does not extract, as a row corresponding to an optimal reading sensitivity, the row containing the abnormal pixel IL1 in which a dynamic range value MA2 in FIG. 22A deviates from  
25 the dynamic range change trend and is a maximum value, but a linearly differentiated value MB2 of the dynamic range in FIG. 22B is not a minimum value.

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Hence, even when a subject image contains the abnormal pixel IL1 due to a foreign substance attached to a fingerprint reading surface, a defect of the photosensor, or the like, a row having a fine contrast corresponding to the ridge/valley pattern of a fingerprint can be reliably extracted to determine an optimal charge accumulating period.

According to the sensitivity setting method of the third embodiment, pre-reading operation is executed while the image reading sensitivity is changed stepwise for respective rows. A row in an optimal image reading state is easily and properly determined based on the dynamic range value of each row to lightness data and the linearly differentiated value of the dynamic range. An image reading sensitivity (charge accumulating period) set for the row can be set as an optimal sensitivity. Normal image reading operation of a subject image can be performed at a proper sensitivity without being influenced by an abnormal pixel generated by a foreign substance attached to a fingerprint reading surface, a defect of the photosensor, or the like.

The third embodiment executes sensitivity setting processing in a sensitivity determination range limited to a row/column range defined by 64th to 191st rows and 67th to 130th columns. However, the present invention is not limited to this, and is applicable to the entire

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region of image data without limiting the sensitivity determination range.

<Fourth Embodiment>

5 The fourth embodiment of a photosensor system drive control method according to the present invention to which the same controller as in the third embodiment can be applied will be described with reference to the several views of the accompanying drawing. The fourth embodiment determines whether an abnormal pixel exists  
10 in image data by applying the sensitivity setting method of the third embodiment.

FIG. 23 is a flow chart showing an operation up to detection processing of an abnormal pixel according to the fourth embodiment in the photosensor system  
15 operation control method using the above-mentioned controller.

In S41 (pre-reading step) of FIG. 23, prior to normal reading operation of a subject image, a main controller 123 controls to set an image reading  
20 sensitivity for pre-reading operation in a sensitivity setting register 127 via a data controller 122, and executes pre-reading operation of reading a subject image at a plurality of different sensitivities while changing the image reading sensitivity stepwise for  
25 respective rows of the subject image. The image reading sensitivities of respective rows are stored as a row number vs. image reading sensitivity

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correspondence table in a RAM 130 in correspondence with row numbers. This pre-reading operation is the same as the operation in the first embodiment, and a detailed method of setting the image reading sensitivity (charge accumulating period) will be described below.

In S42 (image data conversion step) of FIG. 23, the image data read by pre-reading operation is converted into a digital signal via an amplifier 116 and A/D converter 117, and input as lightness data corresponding to the bright/dark pattern of the subject image to a data comparator 124. In this case, the lightness data is expressed by, e.g., 256 gray levels.

In S43 (step of extracting the maximum and minimum values of each row) of FIG. 23, the data comparator 124 extracts the maximum and minimum values of lightness data of each row, and outputs them to an adder 125. That is, the data comparator 124 extracts lightness data representing a maximum value (gray level value of the brightest pixel) contained in each row, and lightness data representing a minimum value (gray level value of the darkest pixel).

In S44 (step of calculating the dynamic range of each row) of FIG. 23, the adder 125 calculates as a dynamic range the difference between the maximum and minimum values of lightness data of each row, and stores the dynamic range in the RAM 130 via the data

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selector 126. The adder 125 executes dynamic range calculation processing for all the rows.

5 In S45 (step of calculating the linearly differentiated value of the dynamic range) of FIG. 23, the dynamic ranges of respective rows stored in the RAM 130 are read out via the data selector 126, and input again to the adder 125, which calculates the difference (linearly differentiated value) between the dynamic ranges of adjacent rows. The results are stored in  
10 the RAM 130 via the data selector 126.

In S46 (step of extracting a row number having a maximum dynamic range and maximum linearly differentiated value) of FIG. 23, data of the dynamic ranges of respective rows and data of the linearly  
15 differentiated values of the dynamic ranges which are stored in the RAM 130 are read out via the data selector 126, and input to the data comparator 124, which extracts a row number at which the dynamic range maximizes and the linearly differentiated value of the  
20 dynamic range maximizes.

In S47 (step of determining presence/absence of an extracted row) of FIG. 23, whether a corresponding row number has been extracted in step S46, i.e., whether a row which satisfies extraction conditions  
25 exists is determined. If a corresponding row number is determined based on the determination result to have been extracted, an abnormal pixel is determined to

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exist in the image data read by pre-reading operation. If no corresponding row number is determined to have been extracted, no abnormal pixel is determined to exist.

5           This abnormal pixel detection processing can determine the presence/absence of a foreign substance attached to the read surface for a subject or the subject itself, or the presence/absence of a defect of the sensor element constituting the photosensor array.  
10       If an abnormal pixel exists, this can be notified with an alarm or the like to execute proper action, and normal reading operation of a subject image can be appropriately done in S48.

15           More specifically, as shown in FIG. 20, a predetermined sensitivity determination range is set on image data of a fingerprint. At this time, if the abnormal pixel IL1 exists in the sensitivity determination range due to a foreign substance attached to a fingerprint reading surface, characteristic  
20       changes and defects of the photosensor, or the like, lightness data of the abnormal pixel IL1 exhibits an excessive value in comparison with peripheral pixel data. In this case, a dynamic range calculated based on the maximum and minimum values of this lightness  
25       data, and its linearly differentiated value appear greatly apart from the remaining normal distribution trend, as shown in FIGS. 21, 22A, and 22B. When the

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abnormal detection method of the fourth embodiment is applied to this situation, a row number L at which the dynamic range exhibits the maximum value MA2 and the linearly differentiated value of the dynamic range exhibits the maximum value MB2 is extracted to determine that the abnormal pixel IL1 exists in the image data. As a result, proper action of, e.g., cleaning the sensing surface to remove the foreign substance can be instructed prior to normal reading operation of a subject image.

Note that the abnormal detection method of the fourth embodiment may be executed singly for a predetermined subject image, or may be executed in parallel with the above-described sensitivity setting method.

<Fifth Embodiment>

The fifth embodiment of a photosensor system drive control method according to the present invention will be described with reference to the several views of the accompanying drawing.

The detailed arrangement and operation of a controller applied to the fifth embodiment will be explained with reference to the several views of the accompanying drawing.

FIG. 24 is a block diagram showing an arrangement of the controller applied to this embodiment. As will be described below, this controller has almost the same

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arrangement as the controller shown in FIG. 2, and the same reference numerals denote the same parts.

As shown in FIG. 24, a controller 120a in the fifth embodiment comprises a device controller 121 for controlling a top gate driver 111, bottom gate driver 112, and output circuit section 113, a data controller 122 for managing various data such as image data, write data, and readout data to a RAM 130, and a main controller 123 which supervises the controllers 121 and 122 and interfaces with an external function section.

The controller 120a further comprises:

an abnormal value removing section 128 constituted by a Fourier transformation section or circuit 128a for Fourier-transforming specific measurement data based on image data input as a digital signal from a photosensor array 100 via an A/D converter 117, a filtering section or circuit 128b for removing a high-frequency component corresponding to an abnormal value from the Fourier-transformed measurement data, and an inverse Fourier transformation section or circuit 128c for inversely Fourier-transforming the measurement data from which the high-frequency component is removed;

a data comparator 124 for extracting maximum and minimum values by comparing the sizes of measurement data from which abnormal values are removed by the abnormal value removing section 128, and for extracting the maximum value of a dynamic range calculated by

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an adder 125 (to be described below) and the minimum value of the difference (linearly differentiated value) between dynamic ranges;

5 the adder 125 for calculating a dynamic range from the difference between the maximum and minimum values of measurement data, and calculating the difference between dynamic ranges, i.e., linearly differentiated value;

10 a data selector 126 for receiving measurement data processed via the A/D converter 117, abnormal value removing section 128, data comparator 124, and adder 125, and switching write/readout in/from the RAM 130, re-input to the data comparator 124 and adder 125, and output to the external function section 200 via the data controller 122 in accordance with the received data; and

15 a sensitivity setting register 127 for changing control signals to be output from the device controller 121 to the top and bottom gate drivers 111 and 112 so as to optimize the reading sensitivity of the photosensor array on the basis of a control signal from the data controller 122.

20 The operation of the fifth embodiment in the operation control method of the photosensor system using the above controller will be explained with reference to FIG. 25. FIG. 25 is a flow chart showing an operation up to read of a subject image with an

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optimal sensitivity according to the fifth embodiment in operation control of the photosensor system. This operation will be described by properly referring to the arrangement of the photosensor system shown in  
5 FIGS. 1 and 24.

In S51 (pre-reading step) of FIG. 25, prior to normal reading operation of a subject image, the main controller 123 controls to set an image reading sensitivity for pre-reading operation in the  
10 sensitivity setting register 127 via the data controller 122, and executes pre-reading operation of reading a subject image at a plurality of different sensitivities while changing the image reading sensitivity stepwise for respective rows of the subject  
15 image. The image reading sensitivities of respective rows are stored as a row number vs. image reading sensitivity correspondence table in the RAM 130 in correspondence with row numbers. This pre-reading operation is the same as the operation in the first  
20 embodiment, and a detailed method of setting the image reading sensitivity (charge accumulating period) will be described below.

In S52 (image data conversion step) of FIG. 25, the image data read by pre-reading operation is  
25 converted into a digital signal via the amplifier 116 and A/D converter 117, and input as lightness data corresponding to the bright/dark pattern of the subject

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image to the abnormal value removing section 128.  
In this case, the lightness data is expressed by, e.g.,  
256 gray levels.

5 In S53 (Fourier transformation step) of FIG. 25,  
the lightness data input to the abnormal value removing  
section 128 is Fourier-transformed by the Fourier  
transformation section 128a on the basis of the  
dynamic range of lightness data of each row to obtain  
a frequency distribution representing the variation  
10 width of lightness data of each row number.

In S54 (high-frequency component removing step)  
of FIG. 25, a high-frequency component equal to or  
higher than a predetermined value is removed from  
the lightness data frequency distribution converted  
15 by the Fourier transformation section 128a. More  
specifically, a predetermined high-frequency component  
is removed by passing the data through the filtering  
section 128b formed from, e.g., a low-pass filter.

In S55 (inverse Fourier transformation step) of  
20 FIG. 25, the frequency distribution from which the  
high-frequency component is removed is inversely  
Fourier-transformed by the inverse Fourier transforma-  
tion section 128c to obtain lightness data of each row  
number again.

25 A series of abnormal value removing operations of  
the abnormal value removing section 128 remove from  
original lightness data a high-frequency component,

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i.e., abnormal value which has a steep variation and deviates from the main change trend of lightness data, and extract only the main component of the lightness data in which the dynamic range changes smoothly for each row. The lightness data from which the abnormal value is removed is input to the data comparator 124.

In S56 (step of extracting the maximum and minimum values of each row) of FIG. 25, the data comparator 124 extracts for each row the maximum and minimum values of the lightness data from which the abnormal value is removed, and outputs them to the adder 125. That is, the data comparator 124 extracts lightness data representing a maximum value (gray level value of the brightest pixel) contained in each row, and lightness data representing a minimum value (gray level value of the darkest pixel).

In S57 (step of calculating the dynamic range of each row) of FIG. 25, the adder 125 calculates as a dynamic range the difference between the maximum and minimum values of lightness data of each row, and temporarily stores the dynamic range in the RAM 130 via the data selector 126. The adder 125 executes dynamic range calculation processing for all the rows.

In S58 (step of calculating the linearly differentiated value of the dynamic range) of FIG. 25, the dynamic ranges of respective rows stored in the RAM 130 are read out via the data selector 126, and input

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again to the adder 125, which calculates the difference (linearly differentiated value) between the dynamic ranges of adjacent rows. The results are stored in the RAM 130 via the data selector 126.

5           In S59 (step of extracting a row number having a maximum dynamic range and minimum linearly differentiated value) of FIG. 25, data of the dynamic ranges of respective rows and data of the linearly differentiated values of the dynamic ranges which are  
10 stored in the RAM 130 are read out via the data selector 126, and input to the data comparator 124, which extracts a row number at which the dynamic range maximizes and the linearly differentiated value of the dynamic range minimizes (to 0 or a value close to 0).

15           In S60 (sensitivity referring/extraction step) of FIG. 25, the row number vs. image reading sensitivity correspondence table stored in the RAM 130 is looked up based on the extracted row number, and an image reading sensitivity, i.e., charge accumulating period set for  
20 this row is extracted.

          In S61 (extracted sensitivity setting step) of FIG. 25, the data controller 122 rewrites the sensitivity setting register 127 to set the image reading sensitivity in the sensitivity setting register  
25 127 to the extracted image reading sensitivity. In S62 (subject image reading step) of FIG. 25, normal reading operation of a subject image is executed at the

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extracted image reading sensitivity set in the sensitivity setting register 127.

5 An example of applying the fifth embodiment of the photosensor system drive control method to a fingerprint reading apparatus will be described with reference to FIGS. 26 to 27B.

10 As will be described below, the fifth embodiment can effectively prevent any malfunction in optimal sensitivity extraction processing even when image data read by pre-reading operation contains an abnormal value, and the abnormal value exists on not only one pixel but across a plurality of pixels. This embodiment can also be effectively applied to a case wherein image data does not contain any abnormal value, 15 which will be described first.

20 Pre-reading operation in the fifth embodiment is the same as that in the above embodiments. The fifth embodiment will exemplify a case wherein image data read by pre-reading operation is the same as image data shown in FIG. 15, and the sensitivity determination range is defined to a row/column range of 64th to 191st rows and 67th to 130th columns.

25 The result of extracting changes in lightness data in the 64th, 96th, 160th, and 191st rows in the sensitivity determination range and plotting them is the same as FIG. 16.

In accordance with the above-mentioned abnormal

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value removing operation, the lightness data distribution of respective rows is Fourier-transformed to obtain a frequency distribution for the row number, a high-frequency component corresponding to an abnormal value or noise is removed, and the resultant data is inversely Fourier-transformed to extract only lightness data representing a main change trend in the lightness data distribution of respective rows. In this case, image data does not contain any abnormal value.

Thus, even if the high-frequency component of lightness data is removed, the lightness data distribution trend does not especially change. Hence, the dynamic range distribution of respective rows is the same as that shown in FIG. 17A. Changes in the linearly differentiated values of respective rows to this dynamic range distribution are also the same as those shown in FIG. 17B. For this reason, a row number extracted under conditions that the dynamic range is maximum and the linearly differentiated value is minimum is the same as in the third embodiment, and an optimal image reading sensitivity based on the extracted row number is also the same as in the third embodiment.

The following description concerns sensitivity setting operation when image data contains an abnormal value owing to a foreign substance attached to a subject or the sensing surface of the photosensor array, a defect of the sensor element constituting

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the photosensor array, or the like.

FIG. 26 is a view showing an example of image data when a subject (fingerprint) image is read while the image reading sensitivity is changed stepwise for respective rows in pre-reading operation. FIG. 27A is a graph showing the dynamic range distribution of lightness data of respective rows when a subject image has a component corresponding to a foreign substance or the like. FIG. 27B is a graph showing the dynamic range distribution of lightness data of respective rows after abnormal value removing operation according to the fifth embodiment.

As shown in FIG. 26, similar to the above-described case, a row/column range of 64th to 191st rows and 67th to 130th columns is set as a sensitivity determination range for read fingerprint image data. In this case, if an abnormal pixel IL2 relatively large enough to overlap a plurality of rows (LA to LB rows) exists in the sensitivity determination range owing to a foreign substance attached to the sensing surface of the photosensor array, a defect of the photosensor element, noise contained in image data, or the like, the lightness data of the abnormal pixel IL2 may exhibit an excessive value in a plurality of rows in comparison with peripheral pixel data, i.e., a value deviating from the change trend of peripheral pixel data. This occurs when, e.g., a relatively large black

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point exists on the white background, or a relatively large white point exists on the black background, and more specifically, when the variation width or dynamic range of lightness data discretely varies in respective rows, or abnormal pixel data MC due to a foreign substance attached to the sensing surface or a defect of an element exists across a plurality of rows (LA to LB rows), as shown in FIG. 27A.

If the sensitivity setting method of the third embodiment is applied without performing abnormal value removing operation, this sensitivity setting method extracts a row in which the dynamic range of lightness data for each row is maximum and the linearly differentiated value is minimum as a row having an optimal image reading sensitivity. Thus, the dynamic ranges of rows on which the abnormal pixel IL2 continuously exists may be recognized to exhibit a maximum value with respect to the main distribution trend of the whole dynamic range. In addition, the linearly differentiated value in a region representing a continuous change exhibits a value close to 0, and may be recognized to be a minimum value. As a result, a row (row between LA and LB) containing the abnormal pixel IL2 irrelevant to a row having an original optimal image reading sensitivity may be mistaken as a row corresponding to an optimal image reading sensitivity. In this case, an improper image reading

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sensitivity (e.g., charge accumulating period longer than an optimal value) is set in the photosensor system. In normal reading operation, a subject image may become, e.g., white.

5           To the contrary, the sensitivity setting method of the fifth embodiment can remove any abnormal value contained in lightness data by performing Fourier transformation to remove a high-frequency component corresponding to an abnormal value or noise prior to  
10           processing of obtaining the optimal value of the reading sensitivity based on the dynamic range of lightness data. As shown in FIG. 27B, an abnormal value greatly deviating from the dynamic range distribution trend of lightness data for the row number  
15           is eliminated, and only smoothed lightness data MD representing a main change trend is extracted. On the basis of the extracted lightness data MD, a row corresponding to a maximum value MA3 of the dynamic range shown in FIG. 27B is extracted as a row having an  
20           optimal image reading sensitivity under the conditions that the dynamic range is maximum and the linearly differentiated value of the dynamic range is minimum.

          Even when a subject image contains the abnormal pixel IL2 relatively large enough to overlap a  
25           plurality of rows owing to a foreign substance attached to the sensing surface of the photosensor array, a defect of the photosensor element, noise contained

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in image data, or the like, a row having a fine contrast corresponding to the ridge/valley pattern of a fingerprint can be reliably extracted to determine an optimal charge accumulating period. The fifth  
5 embodiment can therefore provide a fingerprint reading apparatus capable of reading a high-quality fingerprint image with almost no malfunction.

Note that the fifth embodiment executes sensitivity setting processing while the sensitivity  
10 determination range is limited to a row/column range of 64th to 191st rows and 67th to 130th columns. However, the embodiment is not limited to this, and can also be applied to a case wherein sensitivity setting processing is executed for the entire region of image  
15 data without limiting the sensitivity determination range.

According to the sensitivity setting methods of the above embodiments, a subject image is pre-read while the image reading sensitivity is changed stepwise  
20 for respective rows. A row in an optimal image reading state can be easily determined based on the dynamic range distribution of lightness data of respective rows or the linearly differentiated value of the dynamic range. An image reading sensitivity (charge accumulating  
25 ing period) set for this row can be set as an optimal sensitivity. Hence, the sensitivity can be set by a simple method.

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5 An image reading sensitivity (charge accumulating  
period) set for this row can be set as an optimal  
sensitivity. Normal image reading operation of  
a subject image can be done at a proper sensitivity  
without any influence of an abnormal pixel generated by  
0 a foreign substance attached to the sensing surface of  
the photosensor array, a defect of the photosensor  
element, or the like.

Even if the characteristics of the photosensor change, processing of obtaining an optimal sensitivity from image data attained by the photosensor can be performed to greatly suppress the influence of characteristic changes.

operation in the above-described embodiments will be described with reference to the several views of the accompanying drawing.

FIGS. 28A to 28J are timing charts showing the first embodiment of the image reading sensitivity (charge accumulating period) setting method. This method will be explained by properly referring to the arrangement of the photosensor system shown in FIGS. 1, 2, and 31A.

According to the image reading sensitivity setting method of this embodiment, as shown in FIGS. 28A to 28D, reset pulses  $\phi T_1$ ,  $\phi T_2$ , ...,  $\phi T_n$  are simultaneously applied to respective top gate lines 101 connected to the top gate terminals TG of double-gate photosensors 10 in the row direction, thereby simultaneously starting a reset period  $T_{reset}$ , and initializing the double-gate photosensors 10 of respective rows.

The reset pulses  $\phi T_1$ ,  $\phi T_2$ , ...,  $\phi T_n$  simultaneously fall to end the reset period  $T_{reset}$ . Then, charge accumulating periods  $T_1$ ,  $T_2$ , ...,  $T_{n-1}$ ,  $T_n$  of the double-gate photosensors 10 on all the rows simultaneously start, and charges (holes) are generated and accumulated in the channel regions in accordance with light quantities entering the double-gate photosensors 10 of respective rows from their top gate terminal side.

As shown in FIGS. 28E to 28I, a pre-charge pulse  $\phi_{pg}$  and readout pulses  $\phi_{B1}$ ,  $\phi_{B2}$ , ...,  $\phi_{Bn}$  are applied to change stepwise the charge accumulating periods  $T_1$ ,  $T_2$ , ...,  $T_{n-1}$ ,  $T_n$  set for respective rows by a predetermined delay time  $T_{delay}$  for respective rows. In this case, the delay time  $T_{delay}$  is equal to or longer than the total time of the reset period  $T_{reset}$ , pre-charge time  $T_{prch}$ , and readout time  $T_{read}$ .

Hence, image data read at reading sensitivities different for respective rows constituting a subject image can be attained by one reading operation of the subject image in pre-reading operation performed prior to sensitivity setting processing as described in the above embodiments.

FIGS. 29A to 29J are timing charts showing the second embodiment of the image reading sensitivity (charge accumulating period) setting method. This method will be explained by properly referring to the arrangement of the photosensor system shown in FIGS. 1, 2, and 31A.

According to the image reading sensitivity setting method of this embodiment, as shown in FIGS. 29A to 29D, the reset pulses  $\phi_{T1}$ ,  $\phi_{T2}$ , ...,  $\phi_{Tn}$  are sequentially applied to the respective top gate lines 101 connected to the top gate terminals TG of the double-gate photosensors 10 in the row direction at a time interval of a predetermined delay time  $T_{delay}$ ,

thereby starting the reset period  $T_{\text{reset}}$ , and initializing the double-gate photosensors 10 of respective rows.

5       The reset pulses  $\phi T_1, \phi T_2, \dots, \phi T_n$  fall to end the reset period  $T_{\text{reset}}$ . Then, charge accumulating periods  $TA_1, TA_2, \dots, TA_{n-1}, TA_n$  sequentially start, and charges (holes) are generated and accumulated in the channel regions in accordance with light quantities entering the double-gate photosensors 10 of respective rows from their top gate terminal side.

10       As shown in FIGS. 29E to 29I, the pre-charge pulse  $\phi_{pg}$  and readout pulses  $\phi B_n, \phi B_{n-1}, \dots, \phi B_2, \phi B_1$  are applied to change stepwise the charge accumulating periods  $TA_1, TA_2, \dots, TA_{n-1}, TA_n$  set for respective rows by the predetermined delay time  $T_{\text{delay}}$  for respective rows after the final reset pulse  $\phi T_n$  falls. In this case, the delay time  $T_{\text{delay}}$  is equal to or longer than the total time of the reset period  $T_{\text{reset}}$ , pre-charge time  $T_{\text{prch}}$ , and readout time  $T_{\text{read}}$ .

15       By this pre-reading operation, the charge accumulating periods  $TA_1, TA_2, \dots, TA_{n-1}, TA_n$  set for respective rows increase at a time interval twice the predetermined delay time  $T_{\text{delay}}$ , and thus image data read at reading sensitivities set at a sensitivity adjustment width of several rows or more can be obtained by reading operation of one frame.

20       The image reading sensitivity (charge accumulating

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period) setting method applied to sensitivity setting processing according to the present invention is not limited to the above embodiments. As far as image data of a subject image can be obtained at different reading sensitivities, e.g., a series of processes described in the prior art: reset operation → charge accumulating operation → pre-charge operation → readout operation can be repeated a plurality of number of times at different reading sensitivities, thereby obtaining image data at different reading sensitivities.

Alternatively, any other methods may also be employed.

The effective voltages of signals applied to the top and bottom gates TG and BG of the double-gate photosensor 10 will be described.

As is apparent from FIGS. 28A to 28H, 29A to 29H, and 33A to 33C, the top gate TG receives a high-level signal voltage  $V_{tgh}$  as a reset pulse only for a very short time ( $T_{reset}$ ), and a low-level signal voltage  $V_{tgl}$  for the remaining relatively long period in pre-reading operation and image reading operation.

In the pre-reading operation and image reading periods, the effective voltage applied to the top gate TG greatly shifts to the low-level side. Since an optimal charge accumulating period set for image reading operation is changed and set in accordance with the ambient illuminance or the like if necessary, the effective voltage applied to the top gate TG inevitably

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varies.

In pre-reading operation and image reading operation, the bottom gate BG receives a high-level signal voltage  $V_{bgh}$  only for a very short time ( $T_{read}$ ), and a low-level signal voltage  $V_{bgl}$  for the remaining relatively long period. In the pre-reading and image reading periods, the effective voltage applied to the bottom gate BG also greatly shifts to the low-level side. Since an optimal charge accumulating period set for image reading operation is changed and set in accordance with the ambient illuminance or the like if necessary, the effective voltage applied to the bottom gate BG inevitably varies.

If such a voltage shifted to a voltage of a specific polarity is kept applied to the gate electrode, the gate electrode traps holes to degrade the element characteristics of the double-gate photosensor and change the sensitivity characteristics.

To prevent this, an effective voltage adjusting period for correcting effective voltages applied to the top and bottom gates TG and BG is set after the pre-reading and image reading periods. During the effective voltage adjusting period, e.g., predetermined correction signals for setting an effective voltage applied to the top gate TG to an optimal value  $V_{te}$  of the effective voltage on the top gate side set in accordance with the sensitivity characteristics of the

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double-gate photosensor, and an effective voltage applied to the bottom gate BG to an optimal value  $V_{be}$  of the effective voltage on the bottom gate side are applied. This can suppress changes in sensitivity characteristics caused by degradation in the element characteristics of the photosensor, and can improve the reliability of the photosensor system.

A photosensor system drive control method according to the present invention when the effective voltage adjusting period is set after the pre-reading and image reading periods, as described above, will be described with reference to FIGS. 30A to 30H.

FIGS. 30A to 30H are timing charts showing an embodiment when the effective voltage adjusting period is set after the pre-reading and image reading periods.

As the drive control method during the pre-reading period, the drive control method in FIGS. 29A to 29H described above is applied. The same reference numerals denote the same parts, and a description thereof will be omitted. The reset pulses  $\phi T1$ ,  $\phi T2$ , ...,  $\phi Tn$  are pulse signals whose high and low levels are signal voltages  $V_{tgh}$  and  $V_{tgl}$ , respectively. The readout pulses  $\phi B1$ ,  $\phi B2$ , ...,  $\phi Bn$  are pulse signals whose high and low levels are signal voltages  $V_{bgh}$  and  $V_{bgl}$ , respectively. As the drive control method during the pre-reading period, the operation shown in FIGS. 28A to 28H may be applied. The present invention

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is not limited to these methods.

The drive control method during the image reading period is based on the conventional photosensor system drive control method shown in FIGS. 33A to 33D.

5 To shorten the operation time, photosensors are driven by overlapping the charge accumulating periods of respective rows at timings so as not to overlap reset, pre-charge, and readout pulses. That is, as shown in FIGS. 30A to 30C, the reset pulses  $\phi T1$ ,  $\phi T2$ , ...,  $\phi Tn$   
10 are sequentially applied to the respective top gate lines 101 connected to the top gate terminals TG of the double-gate photosensors 10 in the row direction, thereby starting the reset period  $T_{reset}$ , and initializing the double-gate photosensors 10 of respective  
15 rows. Similar to the above-described pre-reading operation, the reset pulses  $\phi T1$ ,  $\phi T2$ , ...,  $\phi Tn$  are pulse signals whose high and low levels are the signal voltages  $V_{tgh}$  and  $V_{tgl}$ , respectively. Except for timings at which the reset pulses  $\phi T1$ ,  $\phi T2$ , ...,  $\phi Tn$   
20 of high-level  $V_{tgh}$  are applied, the low-level signal voltage  $V_{tgl}$  is applied.

The reset pulses  $\phi T1$ ,  $\phi T2$ , ...,  $\phi Tn$  fall to end the reset period  $T_{reset}$ . Then, optimal light accumulating periods  $T_a$  obtained by each embodiment  
25 for respective rows based on pre-reading operation sequentially start, and charges (holes) are generated and accumulated in the channel regions in accordance

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with light quantities entering the double-gate  
photosensors 10 from their top gate electrode side.  
As shown in FIG. 30G, pre-charge operation of applying  
the pre-charge signal  $\phi_{pg}$  to start the pre-charge  
5 period  $T_{prch}$ , and applying the pre-charge voltage  $V_{prch}$   
to the data line 103 to cause the drain electrode of  
the double-gate photosensor 10 to hold a predetermined  
voltage is performed during the light accumulating  
period  $T_a$ . As shown in FIGS. 30D to 30F, the readout  
10 pulses  $\phi_{B1}$ ,  $\phi_{B2}$ , ...,  $\phi_{Bn}$  are sequentially applied  
in units of rows to the bottom gate lines 102 of  
double-gate photosensors 10 in which the optimal light  
accumulating period  $T_a$  and pre-charge period  $T_{prch}$  end.  
Then, the readout period  $T_{read}$  starts, and voltage  
15 changes  $V_D$  corresponding to charges accumulated in the  
double-gate photosensors 10 are read out from the  
output circuit section 113 via the data lines 103, as  
shown in FIG. 30H. Similar to pre-reading operation  
described above, the readout pulses  $\phi_{B1}$ ,  $\phi_{B2}$ , ...,  $\phi_{Bn}$   
20 are pulse signals whose high and low levels are at the  
signal voltages  $V_{bgh}$  and  $V_{bgl}$ , respectively. Till  
timings at which the readout pulses  $\phi_{B1}$ ,  $\phi_{B2}$ , ...,  $\phi_{Bn}$   
of high-level  $V_{bgh}$  are applied, the low-level signal  
voltage  $V_{bgl}$  has been applied.

25 After image reading operation is completed for all  
the rows, effective voltage adjustment operation of  
adjusting the shifts of the effective voltages of

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signals applied to each gate electrode in the pre-reading and image reading periods and optimizing the effective voltages is executed in the effective voltage adjusting period. More specifically, as shown in  
5 FIGS. 30A to 30C, the top gate line 101 of each row receives a correction signal having a high-level period ( $T_{tph}$ ) and low-level period ( $T_{tpl}$ ) so as to attain a predetermined effective voltage capable of adjusting the effective voltage of a signal voltage applied to  
10 the top gate line 101, i.e., top gate terminal TG of the double-gate photosensor 10 in response to a reset pulse in the pre-reading and image reading periods to an optimal value  $V_{te}$  set in advance in accordance with the sensitivity characteristics of the double-gate  
15 photosensor 10.

Similarly, the bottom gate line 102 of each row receives a correction signal having a high-level period ( $T_{bph}$ ) and low-level periods ( $T_{bpla}$  and  $T_{bplb}$ ) so as to attain a predetermined effective voltage capable of  
20 adjusting the effective voltage of a signal voltage applied to the bottom gate line 102, i.e., bottom gate terminal BG of the double-gate photosensor 10 in response to a readout pulse to an optimal value  $V_{be}$  set in advance in accordance with the sensitivity  
25 characteristics of the double-gate photosensor 10.

As a result, the effective values of voltages applied to the top and bottom gates TG and BG of the

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photosensor element can be set to optimal values to suppress changes in sensitivity characteristics caused by degradation in the element characteristics of the photosensor, and to improve the reliability of the photosensor system.

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